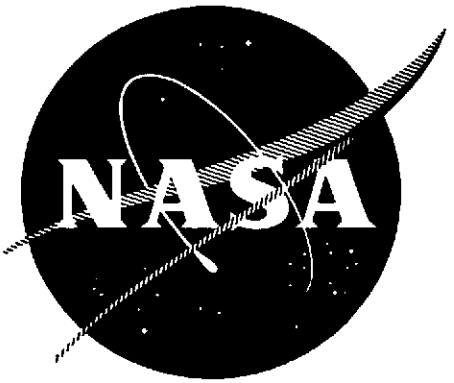
138985



EVALUATION PROGRAM

for

SECONDARY SPACECRAFT CELLS

INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS WITH AUXILIARY ELECTRODES FOR THE ATMOSPHERIC EXPLORER SATELLITE C&D

prepared for

GODDARD SPACE FLIGHT CENTER

CONTRACT S-23404-G

QUALITY EVALUATION AND ENGINEERING LABORATORY

NAD CRANE, INDIANA

DEPARTMENT OF THE NAVY
NAVAL AMMUNITION DEPOT
QUALITY EVALUATION AND ENGINEERING LABORATORY
CRANE, INDIANA 47522

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Enclosure (1)

REPORT BRIEF
GENERAL ELECTRIC COMPANY
6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
WITH AUXILIARY ELECTRODES
FOR THE
ATMOSPHERIC EXPLORER SATELLITE C&D

Ref: (a) NASA P.O. S-23404-G
(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed Space Cells: NAD 3053-TP324, 10 Apr 73

I. TEST ASSIGNMENT BRIEF

A. The purpose of this evaluation test program is to insure that all cells put into the life cycle program are of high quality by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test.

B. The 16 cells were provided by the National Aeronautics and Space Administration, Goddard Space Flight Center, to NAD Crane for evaluation on life test. Thirteen of the cells were purchased by RCA Corporation, under contract number G6F015-0204-00-F23, from General Electric Company, Gainesville, Florida. Six of these cells were identified by RCA lot number 19722-94-1 and seven auxiliary electrode cells by lot number 19722-94-2. These cells are from the same lot of cells that will be flown in the Atmospheric Explorer Spacecrafts C and D. The remaining three cells were purchased by NASA, Goddard Space Flight Center, under contract number NAS5-18495, and were identified by General Electric catalog number 42B006AB37-64. These cells are rated at 6.0 ampere-hours, contain double ceramic seals, and were received with pressure gauge assemblies. The auxiliary electrode is a teflon coated, sintered, nickel plaque located along one side of the narrow edge of the cell. The auxiliary resistor used throughout the test was 2000 ohms. Testing was funded in accordance with reference (a).

C. Test limits specify those values in which a cell is to be terminated from a particular charge or discharge. Requirements are referred to as normally expected values based on past performance of aerospace nickel-cadmium cells with demonstrated life characteristics. A requirement does not constitute a limit for discontinuance from test.

II. SUMMARY OF RESULTS

A. Cell, S/N 054, had leaks at the negative terminal and at the base of its fill tube. This cell did not undergo test and was returned to the Goddard Space Flight Center.

B. The capacity of the cells ranged from 6.6 to 7.6 ampere-hours during the three capacity tests.

C. No voltage requirements or limits were exceeded during any portion of the test.

D. All cells recovered to a voltage in excess of 1.193 volts during the 24-hour open-circuit portion of the internal short test.

E. Two cells, S/N's 065 and 069, delivered 54 percent of the input capacity during the 20°C charge efficiency test. This was below the requirement of 55 percent.

F. Average end-of-charge voltages during the 0°C overcharge test was 1.480 volts with an average end-of-charge pressure of 33 psia. The highest and lowest pressures were 43 and 25 psia respectively. The average capacity out was 6.5 ampere-hours.

G. Pressures, during the 35°C overcharge test, ranged from 22 to 48 psia at the end-of-charge with an average of 39 psia. Average capacity out was 7.4 ampere-hours.

H. All the cells reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltages at this pressure were 9.1 and 1.513 respectively. All cells exhibited pressure decay in the range of 1 to 5 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 7.2 ampere-hours.

III. RECOMMENDATIONS

A. It was recommended that these cells be placed on life test simulating that of the flight batteries in the spacecraft.

B. On 11 December 1973, three 5-cell packs (Packs 2F, 2G and 2H) began life testing on a 2.16-hour orbit (1.52-hour charge) with a voltage limit control at temperatures of 0°, 10° and 20°C.

RESULTS OF INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 6.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS WITH AUXILIARY ELECTRODES FOR THE ATMOSPHERIC EXPLORER SATELLITE C&D

I. TEST CONDITIONS AND PROCEDURE

A. All evaluation tests were performed at room ambient (RA) pressure and temperature (25°C + 2°C), with discharges at the 2-hour rate, and in accordance with reference (b), unless otherwise specified, and consisted of the following:

1. Phenolphthalein leak tests (2).

2. Three capacity tests, third at 20°C; with internal resistance measurements during second charge/discharge.

3. Internal short test.

4. Charge efficiency test, 20°C.

5. Overcharge tests, 0°C and 35°C.

6. Pressure versus capacity test.

7. Phenolphthalein leak test.

See Appendix I for summary of test procedure.

II. CELL IDENTIFICATION AND DESCRIPTION

A. The cells were identified by the manufacturer's serial numbers, catalog number and RCA's serial number and lot number as follows:

Manufacturer's Number		RCA's Number	
Catalog	Serial	Lot	Serial (Not Inclusive)
42B006AB37-G4	003, 006, 009	19722-94-1	049 - 054
		19722-94-2	063 - 070

The cells were placed in temporary pack configurations for initial testing (Packs 509 and 510X).

B. The 6.0 ampere-hour cell is rectangular with an average weight and physical dimensions as follows:

Weight (g)*	Overall Height (in.)	Length (in.)	Width (in.)
640.2	3.559	0.833	2.140

*With pressure gauge assemblies.

C. The cell containers and covers are made of stainless steel. The positive and negative terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder-type terminals.

D. The auxiliary electrode is a teflon coated, sintered, nickel plaque located along one side of the narrow edge of the cell. Its physical dimensions are 1.25 inches by 0.65 inch and has a bag-type enclosure of pellon 2506 K4 material. The auxiliary resistor is 2000 ohms.

III. RESULTS--THE FOLLOWING WAS CONDENSED FROM TABLES I THROUGH V:

A. Leak Tests--One cell, S/N 054, had leaks at its negative terminal and at the base of its fill tube and was not tested, but returned to the Goddard Space Flight Center.

B. Average Capacity (ampere-hours, AH):

Type of Charge	AH Out
C/20, 48 hours RA	7.3
C/10, 24 hours RA	7.4
C/10, 24 hours 20°C	6.9

C. Average Internal Resistance Measurements (milliohms):

Measurement Taken	Resistance
30 min. before end-of-charge (Cycle 1)	4.43
1 hr. after start-of-discharge (Cycle 2)	4.32
2 hrs. after start-of-discharge (Cycle 2)	4.57

D. Twenty-four hour average cell voltage following a 16-hour short period during the internal short test was 1.227 volts and the lowest cell voltage was 1.194 volts.

E. Average capacity out following the 20°C charge efficiency test was 1.70 ampere-hours which represents 56.8 percent efficiency although two cells, S/N's 065 and 069, only delivered 54 percent which was less than the minimum requirement of 55 percent.

F. Average end-of-charge voltages during the 0°C overcharge test was 1.480 volts with an average end-of-charge pressure of 33 psia. The highest and lowest pressures being 43 and 25 psia respectively. The average capacity out was 6.5 ampere-hours.

G. Pressures, during the 35°C overcharge test, ranged from 22 to 48 psia at the end-of-charge with an average of 39 psia. Average capacity out was 7.4 ampere-hours.

H. All the cells reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltages at this pressure were 9.1 and 1.513 respectively. All cells exhibited pressure decay in the range of 1 to 5 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 7.2 ampere-hours.

APPENDIX I

APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Leak Tests:

1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cells and following the last discharge of the cells (Cycle #7).

2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

B. Capacity Tests:

1. The capacity test is a determination of the cells' capacity at the C/2 discharge rate to 0.75 volt per cell, where C is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.

2. The charges for the capacity tests are as follows:

a. C/20, 48 hours, room ambient (R.A.), Cycle 0, with a test limit of 1.52 volts or pressure of 100 psia.

b. C/10, 24 hours, R.A., Cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (65 psia).

c. C/10, 24 hours, 20°C, Cycle 2, with the same limits and requirements as the charge of Cycle 1.

C. Internal Resistance:

1. Measurements are taken across the cell terminals 1/2 hour before the end-of-charge (EOC) on Cycle 1 and 1 and 2 hours after the start-of-discharge of Cycle 2. These measurements were made with a Hewlett-Packard milliohmmmeter (Model 4328A).

D. Internal Short Test:

1. This test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.

2. Following completion of the third capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit-voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of 24 hours.

E. Charge Efficiency Test, 20°C:

1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.

2. The cells are charged at C/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

F. Overcharge Test #1, 0°C:

1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.

2. The cells are charged at C/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 65 psia. The cells are then discharged and 85 percent capacity out of that obtained in Cycle 3 is required.

G. Overcharge Test #2, 35°C:

1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20°C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.

2. The cells are charged at C/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure and a requirement of 1.45 volts or 65 psia pressure. The cells are then discharged with a requirement that capacity out equals 55 percent capacity out as obtained in Cycle 3.

H. Pressure versus Capacity Test:

1. The purpose of this test is to determine the capacity to a pressure and the pressure decay during charge and open circuit stand respectively.

2. Each cell is charged at C/2 to either a pressure of 20 psia or a voltage of 1.550. Recordings are taken on each cell when it reaches 5, 10, 15 and 20 psia pressure. The cells then stand OCV for 1 hour with 30-minute recordings and then are discharged, shorted out and leak tested.

TABLE I

SERIAL NUMBER	WEIGHT** (Grams)	HEIGHT (Inches)	LENGTH (Inches)	WIDTH (Inches)	PHENOLPHTHALEIN LEAK TESTS											
					Initial				Following Hi Vac				Following Test Completion			
					Terminals		Fill Tube	Other	Terminals		Fill Tube	Other	Terminals		Fill Tube	Other
					+	-			+	-			+	-		
003	633.9	3.564	.826	2.140												
006	633.3	3.561	.830	2.147												
009	633.6	3.559	.832	2.128												
049	632.6	3.546	.840	2.136												
050	648.2	3.565	.832	2.138												
051	650.5	3.568	.840	2.136						No Leaks.				No Leaks		
052	652.1	3.552	.832	2.144												
053	638.9	3.559	.832	2.152												
054*	648.9	3.556	.836	2.136		✓	base									
063	635.1	3.544	.827	2.135												
064	633.7	3.562	.841	2.136												
065	636.8	3.564	.832	2.142												
066	635.3	3.557	.828	2.144												
068	638.9	3.560	.832	2.154												
069	637.5	3.566	.832	2.136												
070	652.2	3.568	.832	2.140												

* Was not tested, sent back to Goddard Space Flight Center

** All cells equipted with pressure gauges

TABLE II
CAPACITY DATA

SERIAL NUMBER	CAPACITY TEST #1						CAPACITY TEST #2						CAPACITY TEST #3 (20°C)					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	* PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
003	1.445	N/a	14	7.3	N/a	5	1.447	N/a	22	7.3	N/a	4	1.465	N/a	15	7.1	N/a	5
006	1.449	N/a	12	7.4	N/a	4	1.449	N/a	19	7.4	N/a	5	1.469	N/a	22	6.6	N/a	6
009	1.444	N/a	12	7.5	N/a	4	1.446	N/a	20	7.5	N/a	3	1.464	N/a	15	7.3	N/a	4
049	1.445	N/a	13	7.3	N/a	2	1.449	N/a	30	7.4	N/a	3	1.471	N/a	26	6.8	N/a	5
050	1.445	N/a	17	7.3	N/a	6	1.450	N/a	31	7.5	N/a	5	1.473	N/a	29	6.7	N/a	9
051	1.444	N/a	13	7.3	N/a	5	1.449	N/a	26	7.3	N/a	5	1.470	N/a	30	6.6	N/a	9
052	1.440	N/a	14	7.4	N/a	4	1.445	N/a	23	7.6	N/a	2	1.469	N/a	24	7.0	N/a	4
053	1.443	N/A	12	7.4	N/a	4	1.448	N/a	23	7.6	N/a	6	1.467	N/a	29	6.7	N/a	7
063	1.444	.548	14	7.2	-.013	5	1.450	.632	28	7.3	.091	5	1.469	.630	31	6.8	.117	6
064	1.443	.521	21	7.2	.039	9	1.448	.612	34	7.2	.133	8	1.470	.576	30	7.0	.161	10
065	1.442	.542	17	7.2	.048	5	1.448	.621	28	7.2	.123	5	1.475	.587	26	7.0	.119	7
066	1.443	.618	14	7.2	.139	4	1.448	.681	24	7.3	.197	2	1.470	.678	28	6.8	-.012	4
068	1.443	.546	11	7.3	.061	4	1.448	.635	21	7.4	.102	3	1.470	.635	25	7.0	-.034	9
069	1.442	.569	16	7.2	.063	4	1.449	.678	33	7.1	.138	3	1.471	.640	29	6.9	.130	4
070	1.444	N.A.	15	7.2	N.A.	5	1.449	N.A.	26	7.3	N.A.	5	1.471	N.A.	33	6.7	N.A.	10

N.A. - Not Available

* - charge interrupted for 1 hour after 20 hours of charge in which pressures decreased an average of 5 PSIA

TABLE III
INTERNAL RESISTANCE AND SHORT TEST DATA

SERIAL NUMBER	INTERNAL RESISTANCE (MILLIOHMS)			INTERNAL SHORT TEST		
	END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 24 HOUR OCV STAND	
				CELL	CELL	PRESS
003	4.3	4.2	4.9	.008	1.199	3
006	4.9	4.3	4.8	.038	1.240	4
009	4.4	4.3	4.4	.002	1.194	4
049	4.3	4.3	4.4	.029	1.237	2
050	4.9	4.3	4.4	.032	1.242	4
051	4.3	4.3	4.5	.077	1.247	3
052	4.4	4.1	4.5	.017	1.232	2
053	4.3	4.3	4.5	.186	1.249	3
063	4.4	4.2	4.6	.018	1.236	5
064	4.2	4.2	4.5	.013	1.208	9
065	4.6	4.3	4.6	.013	1.208	4
066	4.4	4.6	4.7	.017	1.235	2
068	4.1	4.5	4.5	.016	1.232	2
069	4.4	4.5	4.7	.013	1.209	4
070	4.5	4.4	4.6	.027	1.239	5

TABLE IV
CHARGE EFFICIENCY AND OVERCHARGE DATA

SERIAL NUMBER	CHARGE EFFICIENCY (20°C)						OVERCHARGE TEST (0°C)						OVERCHARGE TEST (35°C)					
	END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE			END-OF-CHARGE			END-OF-DISCHARGE		
	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY * (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)	CELL (Volts)	AUX ELECT (Volts)	PRESS (PSIA)	CAPAC-ITY (ah)	AUX ELECT (Volts)	PRESS (PSIA)
003	1.371	N/A	4	1.65	N/A	4	1.480	N/A	30	6.7	N/A	9	1.409	N/A	35	7.4	N/A	7
006	1.371	N/A	4	1.80	N/A	5	1.484	N/A	33	6.2	N/A	10	1.407	N/A	45	7.3	N/A	8
009	1.371	N/A	4	1.65	N/A	2	1.478	N/A	25	7.0	N/A	5	1.409	N/A	22	7.7	N/A	7
049	1.373	N/A	2	1.65	N/A	2	1.485	N/A	33	6.4	N/A	9	1.407	N/A	40	7.4	N/A	5
050	1.373	N/A	4	1.73	N/A	5	1.483	N/A	43	6.4	N/A	13	1.408	N/A	48	7.4	N/A	9
051	1.373	N/A	3	1.73	N/A	3	1.482	N/A	41	6.3	N/A	14	1.407	N/A	45	7.3	N/A	8
052	1.373	N/A	2	1.73	N/A	2	1.481	N/A	30	6.7	N/A	6	1.409	N/A	38	7.5	N/A	6
053	1.373	N/A	3	1.73	N/A	3	1.483	N/A	38	6.2	N/A	13	1.408	N/A	40	7.4	N/A	8
063	1.373	.232	5	1.72	.156	4	1.477	.541	32	6.3	.164	9	1.409	.748	42	7.3	.186	7
064	1.374	.169	10	1.69	.097	10	1.476	.483	34	6.8	.111	14	1.412	.677	40	7.4	.224	11
065	1.373	.110	4	1.63	.013	4	1.479	.486	33	6.8	.140	10	1.413	.668	32	7.4	.197	7
066	1.373	.193	2	1.72	.128	2	1.478	.582	33	6.3	.201	7	1.410	.738	41	7.3	.272	5
068	1.373	.202	2	1.75	.135	2	1.476	.553	27	6.5	.170	9	1.410	.715	35	7.4	.198	6
069	1.373	.116	41	1.63	.084	4	1.478	.632	28	6.6	.210	9	1.413	.809	38	7.2	.274	6
070	1.373	N.A.	5	1.75	N.A.	5	1.478	N.A.	35	6.3	N.A.	10	1.410	N.A.	45	7.2	N.A.	8

N.A. - Not available

* - All cells recessed, -.135 to -.193 except cell S/N 063; but no pressure build-up

TABLE V
PRESSURE VS. CAPACITY TEST DATA

Serial No.	003	006	009	049	050	051	052	053	063	064	065	066	068	069 *	070	
Start-of-Charge, Press.	4	5	3	2	4	5	2	5	4	5	5	2	5	5	5	
AH in to 5 PSIA	8.1	n/a	8.9	9.0	1.1	n/a	9.0	n/a	8.3	n/a	n/a	8.4	n/a	n/a	n/a	
Cell (volts)	1.455		1.495	1.490	1.391		1.504		1.462			1.482				
Aux (volts)	n/a		n/a	n/a	n/a		n/a		.455			.568				
AH in to 10 PSIA	8.7	8.9	9.0	9.0	9.0	9.0	9.1	9.1	8.6	8.6	8.5	8.6	8.7	8.4	8.6	
Cell (volts)	1.497	1.510	1.499	1.506	1.504	1.508	1.508	1.510	1.494	1.496	1.486	1.501	1.498	1.486	1.493	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.565	.518	.482	.628	.563	.442	.688	
AH in to 15 PSIA	8.9	9.0	9.0	9.2	9.1	9.1	9.2	9.2	8.8	8.8	8.6	8.8	8.8	8.6	8.6	
Cell (volts)	1.505	1.517	1.502	1.514	1.508	1.511	1.511	1.514	1.505	1.508	1.497	1.507	1.502	1.496	1.498	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.615	.565	.523	.656	.595	.492	.716	
AH in to 20 PSIA	9.0	9.1	9.2	9.3	9.3	9.2	9.3	9.3	9.0	9.0	8.9	8.9	8.9	8.9	8.8	
Cell (volts)	1.507	1.521	1.503	1.518	1.516	1.514	1.514	1.517	1.511	1.515	1.515	1.511	1.507	1.514	1.508	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.657	.613	.616	.682	.644	.629	.760	
AH in to V/L (1.55V)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
Aux (volts)																
Press (PSIA)																
30 Min OCV, Cell	1.402	1.407	1.406	1.409	1.408	1.406	1.404	1.407	1.405	1.399	1.399	1.404	1.402	1.400	1.402	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.598	.569	.565	.633	.598	.646	.700	
Press (PSIA)	22	23	17	23	24	22	18	22	19	20	22	20	18	25	18	
1 hour OCV, Cell	1.393	1.397	1.396	1.398	1.397	1.396	1.394	1.397	1.393	1.388	1.389	1.393	1.391	1.389	1.392	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.565	.549	.542	.607	.566	.614	.671	
Press (PSIA)	19	20	15	18	21	21	15	21	18	17	19	16	16	22	16	
EOD AH out	7.1	7.2	7.3	7.4	7.4	7.2	7.3	7.3	7.2	7.2	7.2	7.2	7.2	7.1	7.2	
Aux (volts)	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	.224	.251	.198	.303	.227	.226	.238	
Press (PSIA)	6	7	4	7	7	7	4	7	6	7	7	5	6	6	6	

* Reached 27 PSIA before cut-out

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